they occupy but a very small fraction of the contents of the cubic centimetre, but yet their number is so great that they would, if placed in line touching one another, go round many times the circumference of the earth, a pretty fair illustration of Euclid's definition of a line.

These molecules, however, are not at rest, but are moving, even at the low temperature I have named, with great velocity, the molecules of the different gases moving with different velocities dependent upon their molecular weight. Thus, the hydrogen molecules which have the highest velocity move with about 5500 feet-seconds mean velocity, while the slowest, the carbonic anhydride molecules, have only 1150 feet-seconds mean velocity, or about the speed of sound.

But in the particular gun under discussion, when the charge was exploded there were no less than 20,500 cubic centimetres of gas, and each centimetre at the density of explosion contained 580 times the quantity of gas—that is, 580 times the number of molecules that I mentioned. Hence the total number of molecules in the exploded charge is $8\frac{1}{3}$ quadrillions, or let us say approximately for the total number eight followed by twenty-four cyphers.

It is difficult for the mind to appreciate what this immense number means, but it may convey a good idea if I tell you that if a man were to count continuously at the rate of three a second, it would take him 265 billions of years to perform the task of counting them.

So much for the numbers; now let me tell you of the velocities with which, at the moment of explosion, the molecules were moving. Taking first the high-velocity gas, the hydrogen, the molecules of the gas would strike the projectile with a mean velocity of about 12,500 feet-seconds. You will observe I say mean velocity, and you must note that the molecules move with very variable velocities. Clerk Maxwell was the first to calculate the probable distribution of the velocities. A little more than one-half will have the mean velocity or less, and about 98 per cent. will have 25,000 feet-seconds or less. A very few, about one in 100 millions, might reach the velocity of 50,000 feet-seconds.

The mean energy of the molecules of different gases at the same temperature being equal, it is easy from the data I have given to calculate the mean velocity of the molecules of the slowest moving gas, carbonic anhydride, which would be about 2600 foot-seconds.

I have detained you, I fear, rather long over these figures, but I have done so because I think they throw some light upon the extraordinary violence that some explosives exhibit when detonated. Take, for instance, the lyddite shell exploded by detonation I showed you earlier in the evening. I calculate that that charge was converted into gas in less than the 1/60,000th part of a second, and it is not difficult to conceive the effect that these gases of very high density suddenly generated, the molecules of which are moving with the velocities I have indicated, would have upon the shell.

The difference between the explosion of gunpowder fired in a close vessel, and that of gun-cotton or lyddite when detonated, is very striking. The former explosion is noiseless, or nearly so. The latter, even when placed in a bag, gives rise to an exceedingly sharp metallic ring, as if the vessel were struck a sharp blow with a steel hammer.

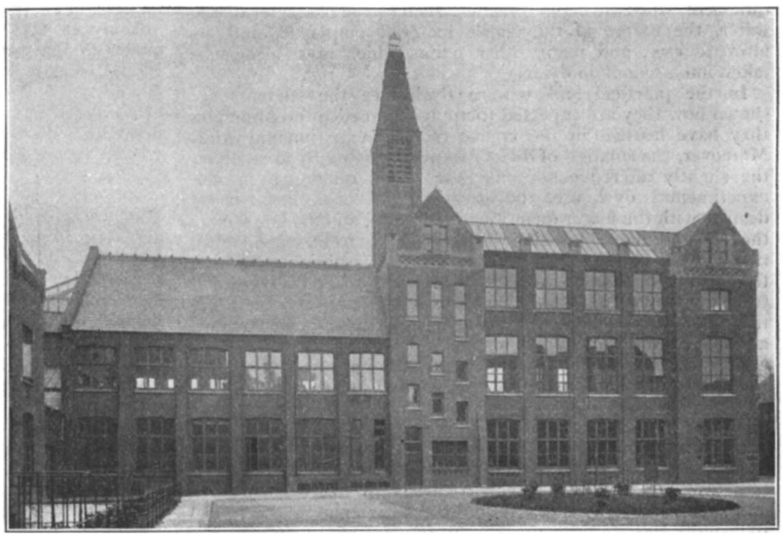
But I must conclude. I began my lecture by recalling some of the investigations I described in this place a great many years ago. I fear I must conclude in much the same way as I then did, by thanking you for the attention with which you have listened to a somewhat dry subject, and by regretting that the heavy calls made on my time during the last few months have prevented my making the lecture more worthy of my subject and of my audience.

EXTENSIONS OF THE DYEING DEPARTMENT OF YORKSHIRE COLLEGE.

THE opening of the extensions in the Clothworkers' Departments of Yorkshire College, Leeds, has already been referred to (p. 69). The new buildings, which are shown in the accompanying illustration, comprise practical and pattern dye-houses and a research laboratory; and, as with several other parts of Yorkshire College, they owe their erection to the generous interest taken in technical education by the Clothworkers' Company of London.

The Clothworkers' Departments of the Yorkshire College consist of textile industries, dyeing and art. The buildings occupied by these departments have been erected by the Clothworkers' Company at a cost of about 60,000*l.*; they are spread over an area of about one-and-a-half acres, and have been specially arranged and equipped for the teaching of all the subjects connected with the designing and manufacturing of woven fabrics.

The Dyeing Department of the Yorkshire College was established in 1880, and the head of the department is Prof. J. J. Hummel. Although the accommodation at first provided was extremely limited, it nevertheless sufficed to show that a demand for instruction in dyeing really existed, and that a continuous supply of students for this subject was available. In due time it was found desirable to increase the facilities for experimental work, and in 1885 the Clothworkers' Company of London erected and equipped, at an expense of about 12,000*l.*, the front portion of the handsome and commodious building at present occupied.



New Buildings of the Dyeing Department of Yorkshire College.

It was felt some years ago that the work of the different departments might be connected. It was considered desirable, for example, that the coloured yarns employed in the weaving department should be dyed by the students in the dyeing department, so that, if at the same time these yarns could also be manufactured on the premises by the establishment of a spinning department, it would become possible to teach the whole routine of clothworking, from the wool in the raw state to the finished cloth. Acting upon this idea, the Clothworkers' Company decided to make the necessary provision for carrying out the scheme suggested, and to extend both the weaving and dyeing departments, at a cost of about 25,000*l.* In connection with the dyeing department, it was arranged to build a three-storied building, to provide two additional dyehouses in which practical dyeing could be carried on, and also a research laboratory for the prosecution of scientific investigations connected with dyestuffs and dyeing.

In July 1896, the foundation stone of the new Clothworkers' Research Laboratory and the other extensions was laid by the

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Master of the Clothworkers' Company, and the completed buildings were opened on May 11.

At the present time, therefore, the dyeing department of the Yorkshire College is represented by a building of considerable dimensions, and so comprehensive in character and equipment as practically to meet every requirement for the purpose of giving a complete theoretical and practical instruction in the art of dyeing in all its branches.

Some idea of the magnitude of the work done in the dyeing department of Yorkshire College may be gained from the fact that each session over 200,000 dyed patterns are distributed. Each student, according to the time spent in the dyehouse, receives during his course of instruction from 2000 to 20,000 patterns, each of which conveys a definite piece of information on some point connected with the application of this or that colouring matter. Not only is the behaviour in the dyebath of each colouring matter investigated, but notes of the results obtained are made by the students during the progress of the work. Further, each student enters in his own book all the patterns received, together with notes of the materials employed, and the results of each experiment. Hence the students not only learn how to experiment and discover the capabilities of each colouring matter for themselves, but they also acquire the useful habit of observing and of making notes, while their pattern books contain a fund of information which is invaluable to them in their after career. The systematic training which they receive also prepares them to deal with the variable conditions of work in actual practice, such as the character of the water, the nature of the textile material employed and its ultimate uses, and many other points which must always be taken into account in dyeing.

In the practical and pattern dyehouses the students are shown how they are expected to apply in practice the principles they have learned in the course of their experimental work. Moreover, the solution of difficulties which naturally arise under the slightly altered conditions from those obtaining in the experimental dyehouse, the greater confidence inspired by dealing with the larger quantities of material, and the knowledge that the products of their labour are really to be employed in the manufacture of cloth, are all factors of inestimable value in the training of the students before they enter into actual practice, to which they are as it were brought indeed one step nearer by the character of the work pursued. Altogether, the students are able, in the College dyehouses, to gain at least some insight as to the meaning and value of practical experience, and an influence is exerted which reacts by giving life and vigour to the work of the whole department.

The art of dyeing owes much to science, and in a University College like the Yorkshire College, it is not unreasonable to expect that students of the art should, in return, contribute something to science, more particularly to that branch of it which pertains to dyeing. If in the experimental and practical dyehouses the students are taught the *art* of dyeing, in the Clothworkers' Research Laboratory they are also urged to study the *science* of dyeing. The aim here is to assist in the work of gaining a fuller and truer knowledge of the fundamental laws and principles connected with dyestuffs and dyeing, and so help to raise, as far as possible, the whole tone and level of the dyeing trade, by infusing into it the traits of an exact science. The carrying on of original research by advanced students has already become, indeed, a marked feature of the department, and the Clothworkers' Company have, in a special way, recognised the value of such work by establishing a lectureship, the holder of which devotes his whole time to co-operating with the professor in introducing students to this higher form of study.

This research work, too, has an intimate connection with Prof. Hummel's lectures, in the course of which are described the methods employed in preparing the coal-tar colours, in isolating the pure colouring principles of dyewoods, and in studying the chemistry of mordanting, dyeing, &c. By allowing the students to carry out similar experiments themselves, the College enables them to understand, in a clearer manner than is otherwise possible, how our knowledge concerning dyestuffs and dyeing has been acquired, and it is hoped that by reason of the practical experience thus gained in the art of research, some students may, in due time, become independent investigators.

The Clothworkers' Research Laboratory is an addition which gives completeness to the means of instruction in dyeing already furnished. The advanced students are thereby provided with the facilities for extending the boundaries of science connected with dyeing, and it is hoped that many young men will take advantage of the opportunity thus given. If in the pursuit of this object the authorities at Yorkshire College can succeed in attracting and training a band of earnest workers; if a well-recognised and successful School of Research in Dyeing is established, side by side with the School of Practical Dyeing, it cannot but be of inestimable value from an educational as well as from a practical point of view, for, if the students, before they leave the College, are taught to contribute to the general sum of knowledge it it surely education in the truest and best sense of the term.

MR. NIKOLA TESLA'S RECENT ELECTRICAL EXPERIMENTS.

A REMARKABLE paper, by Mr. Nikola Tesla, appears in the June number of the *Century Magazine*. The subject is "The Problem of Increasing Human Energy, with Special Reference to the Harnessing of the Sun's Energy"; and though metaphysical and sociological questions receive a large share of attention, the article contains an account of some very interesting electrical experiments, now described for the first time, illustrated by several very striking photographs, two of which are here reproduced. Mr. Tesla has been engaged for several years in further investigating the properties of alternate currents of high potential and frequency, with which he astonished audiences at the Royal Institution in 1892 (see NATURE, vol. xlv. p. 345). The following abstract of a part of his paper shows that his work has led to results of scientific interest and significance.

Electrical discharges capable of making atmospheric nitrogen combine with oxygen have recently been produced. Experiments made since 1891 showed that the chemical activity

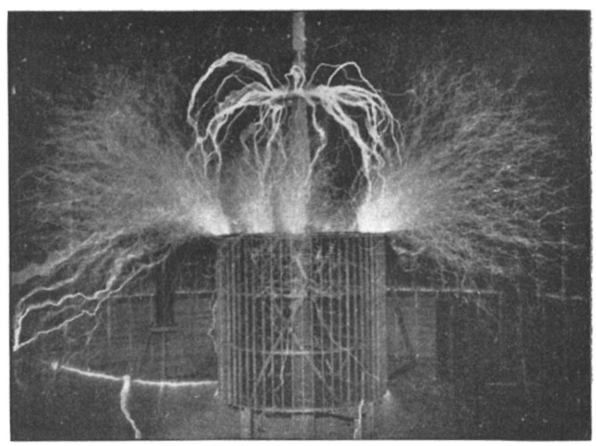

FIG. 1.—Combustion of atmospheric nitrogen by the discharge of an electrical oscillator giving twelve million volts and alternating 100,000 times per second. The flame-like discharge shown in the photograph measured 65 feet across.

of the electrical discharge was very considerably increased by using currents of extremely high frequency or rate of vibration. This was an important improvement, but practical considerations soon set a definite limit to the progress in this direction. Next, the effects of the electrical pressure of the current impulses, of their wave-form and other characteristic features, were investigated. Then the influence of the atmospheric pressure and temperature and of the presence of water and other bodies was studied, and thus the best conditions for causing the most intense chemical action of the discharge and securing the highest efficiency of the process were gradually ascertained. The flame grew larger and larger, and its oxidising action more and more intense. From an insignificant brush-discharge a few inches long it developed into a marvellous electrical phenomenon, a roaring blaze, devouring the nitrogen of the atmosphere and measuring sixty or seventy feet across (Fig. 1). The flame-like discharge visible is produced by the

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